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COMPARISON OF PROTOTYPE DIESEL/MINERAL MONITORS AGAINST A SIMSLIN II

S. HARDCASTLE

ELLIOT LAKE LABORATORY

FEBRUARY 1985

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by

S. Hardcastle*

ABSTRACT

A Simslin II unit has been used for calibration of, and comparison with two prototype diesel/mineral monitors in various respirable dust concentrations. These monitors, using a similar light-scattering technique, have been designed for underground use, but have no intrinsic safety certification.

As a mineral monitor the units compared to within 10% of the Simslin II. Zero drift was apparent in the diesel and mineral readings and needed compensating.

No diesel evaluation was performed, but interaction from mineral was noticed and corrected.

These units would appear to provide a very economic alternative to the Simslin II units.

*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.

COMPARAISON ENTRE LES PROTOTYPES D'APPAREIL DE SURVEILLANCE DES ÉMISSIONS DE MOTEURS DIESEL ET DE LA CONCENTRATION DES PARTICULES MINÉRALES ET LE SIMSLIN II

par

S. Hardcastle*

RÉSUMÉ

On a utilisé un appareil Simslin II dans le but de calibrer et de le comparer à deux prototypes d'appareil servant à mesurer les émissions de moteurs diesel et la concentration des particules minérales, dans des conditions où les concentrations de poussière étaient variées. Ces appareils de surveillance, utilisant une technique similaire de diffusion de la lumière, ont été conçus pour un usage souterrain mais n'ont aucune certification intrinsèque de sécurité.

En tant qu'appareil servant à mesurer la concentration des particules minérales, ces appareils sont comparables à moins de 10 % au Simslin II. On a noté qu'une dérive nulle était apparente pour les lectures des émissions de moteurs diesel et des concentrations des particules minérales et qu'elle avait besoin d'être compensée.

Aucune évaluation des émissions de moteurs diesel n'a été faite, mais une interaction des particules minérales a été observée et corrigée.

Enfin, ces installations semblent fournir une solution de rechange très économique aux appareils Simslin II.

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*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake (Ontario).

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INTRODUCTION

Underground environmental monitors are necessary to study short and long period changes of pollutants in dynamic ventilation systems.

Dust and other airborne particulate matter are extremely important elements to monitor; the development of instruments to perform this, both on general survey and analytical scales are essential (1).

Two prototype differentiating diesel/mineral sensors have been developed for CANMET by Metrex Instruments Ltd., Brampton, Ontario, under Contract No. 26SQ.23440-3-9091 (2).

The two units are nephalometers, they are suitable for continuous monitoring and may be interfaced to underground telemetry systems.

This report outlines the first extensive testing of the units. This was performed under various concentrations of coal dust in the Elliot Lake Laboratory dust chamber. A Simslin II was used for comparison.

The Simslin II, extensively used by the National Coal Board is well established and may be accepted as a nephalometric standard.

These tests determine the mineral calibration of the Metrex units and also the mineral contribution in the diesel calibration.

UNIT DESCRIPTIONS

The Simslin (Safety in Mines Scattered Light Instrument) is shown in Fig. 1 and 2: infra-red radiation is emitted from a laser diode, which is focused onto a column of air drawn through the instrument. The flow, 0.625 L/min, is drawn through an elutriator to remove non-respirable dust. These match the retention characteristics of the MRE/113A. Respirable dust in the airstream scatters a fraction of the light through forward angles of 12-20°, which is focused onto a detector that produces a proportional electrical

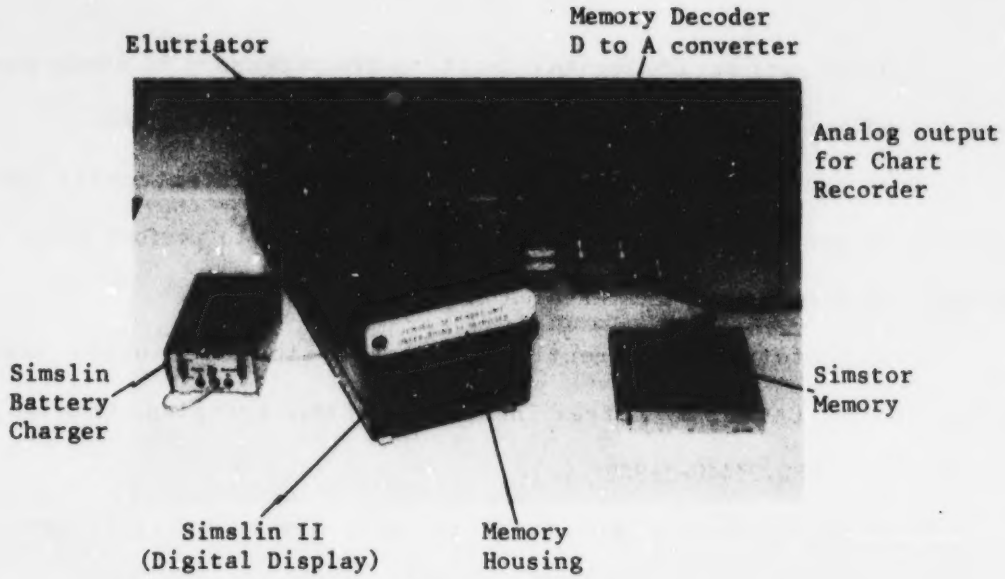

Fig. 1 - The Simslin II, an intrinsically safe real-time dust monitor.

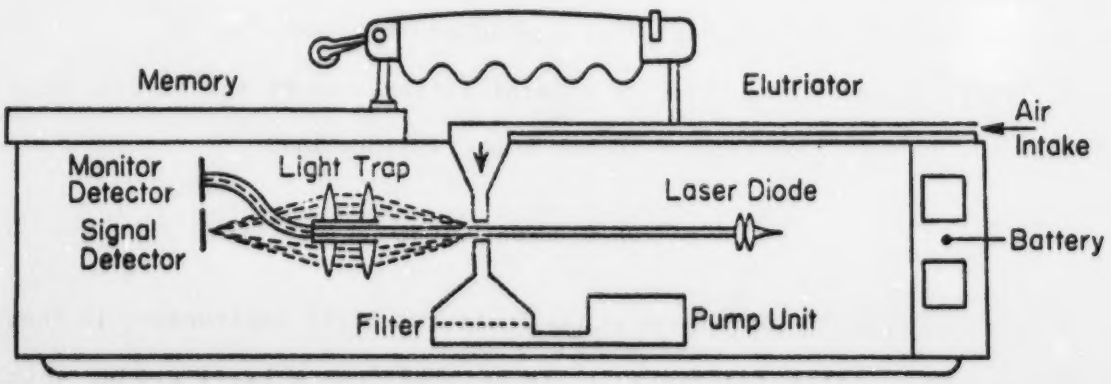

Fig. 2 - General schematic of the Simslin II.

signal. This, once calibrated, will give a direct reading in mg/m^3. The 'continuous' data can be fed to a chart recorder, a data acquisition system, or its internal memory.

After the light scattering volume, the air is filtered to remove respirable dust for later weighing and analysis. This can also be used to calibrate the nephalometer.

The Metrex monitors, Fig. 3 to 5 work on a similar principle to the Simslin above. These units use two light-emitting diodes, each placed to give an optimum forward scatter for two different size ranges of mineral and diesel pollutants. The Metrex units use a 30° angle for mineral dust, and 90° for diesel. These units, however, are open to natural draughts and not a forced flow. Similar data processing is also available.

TESTING PROCEDURE

Five comparative tests between the two diesel/mineral sensors and a Simslin II were performed. This limit was imposed by an instrument malfunction.

The five tests were all performed in assumed homogeneous concentrations of respirable coal dust within a test chamber. Test duration varied from 60 to 150 minutes, and the dust concentration varied through 0-15.1 mg/m^3 with an average of 5.3 mg/m^3.

All tests were a direct comparison of nephalometer outputs, and no gravimetric readings were taken due to the relatively short test duration.

For the two diesel/mineral sensors and the Simslin unit, readings were logged every minute. Before and after each test stable background readings in clean air were obtained for all units.

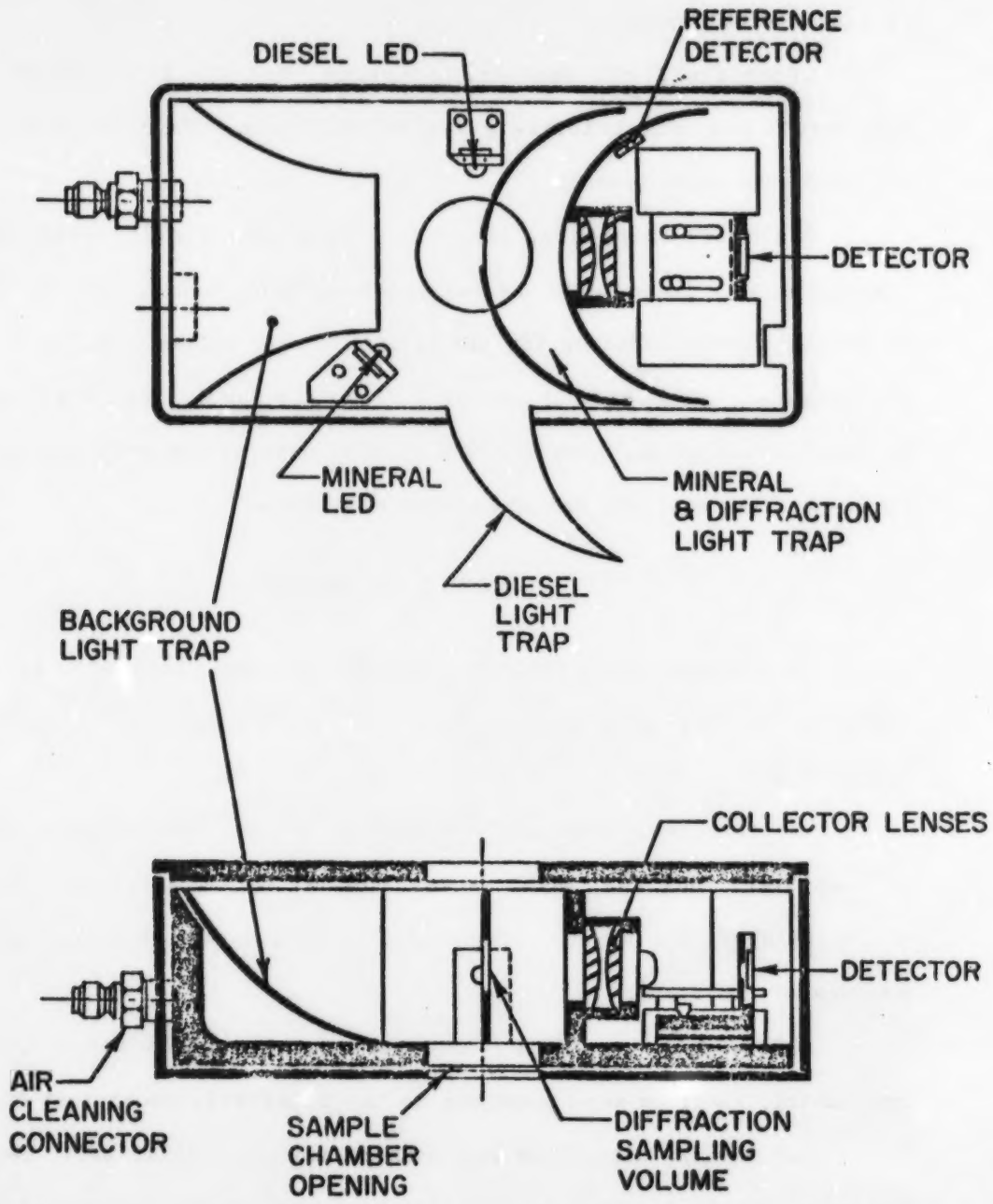

Fig. 3 - Two views of the sensing head in a Metrex diesel/mineral monitor.

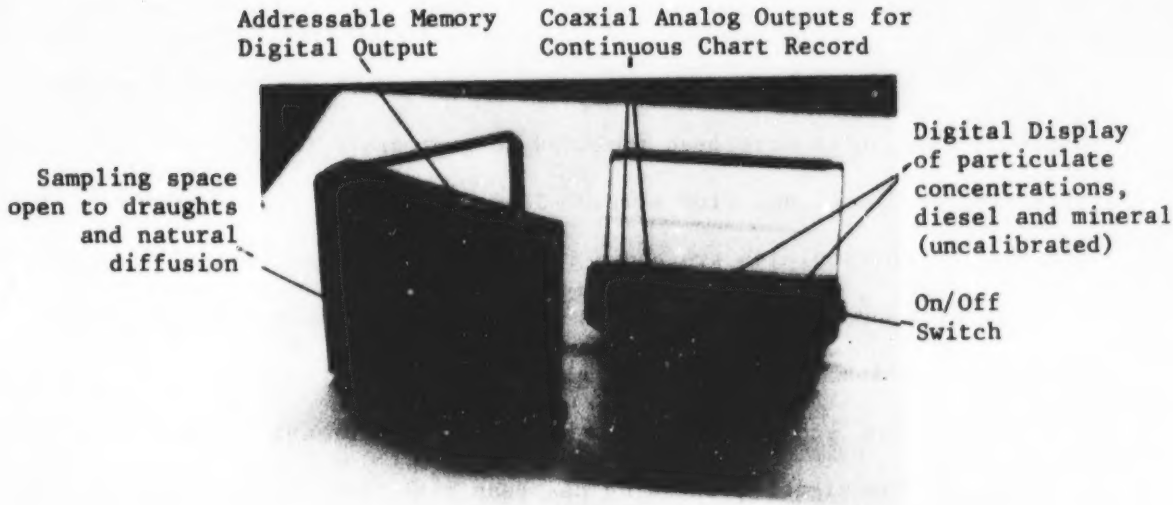

Fig. 4 - Prototype diesel/mineral real-time sensor developed by Metrex Instruments.

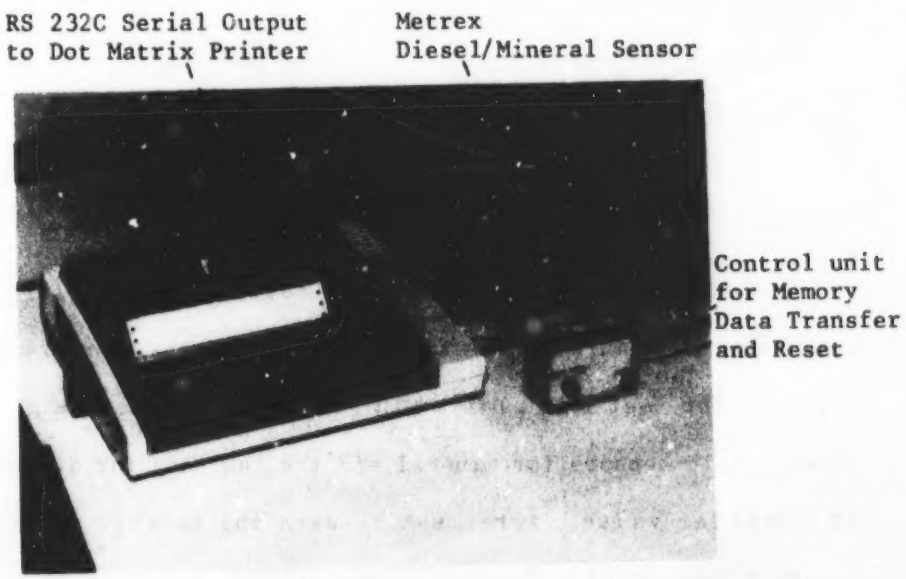

Fig. 5 - Sensor interfaced to printer for memory down-load.

SENSOR DATA PROCESSING

The diesel/mineral sensors have built-in signal processing capabilities, which have been included to compensate for mineral particulates appearing as diesel and vice versa. The assumed size distributions of diesel and mineral particulates are shown in Fig. 6. Although the positioning of the LED's in each unit has been optimized to give peak light scattering with peak size distribution, some interaction remains.

In these and subsequent tests, until the units have been fully calibrated, the signal processing has been minimized and the compensation for diesel/mineral overlap has been omitted. The resulting data will be processed manually.

This first test series was performed with a pure mineral dust cloud. This facilitated the units' calibration for mineral sensitivity and the 'diesel' response to mineral dust.

Subsequent test series should be performed in pure diesel clouds, and then in known mixtures of mineral and diesel particulates.

DATA ANALYSIS AND SENSOR CALIBRATION

The data logged from the diesel/mineral sensors needed extensive computations to turn them into comparable formats. An example of this initial raw data for Test I is plotted in Fig. 7; this shows a good trend agreement between both sensors for mineral and the tendency for diesel to shadow mineral at a smaller value. Agreement between the sensors and Simslin are not yet apparent because of differing sensitivities.

The initial raw data with subsequent processed results for Test I is given in Table 1. The Appendix contains the data and processed results for Tests II to V. The tabulated data were processed by the following routine:

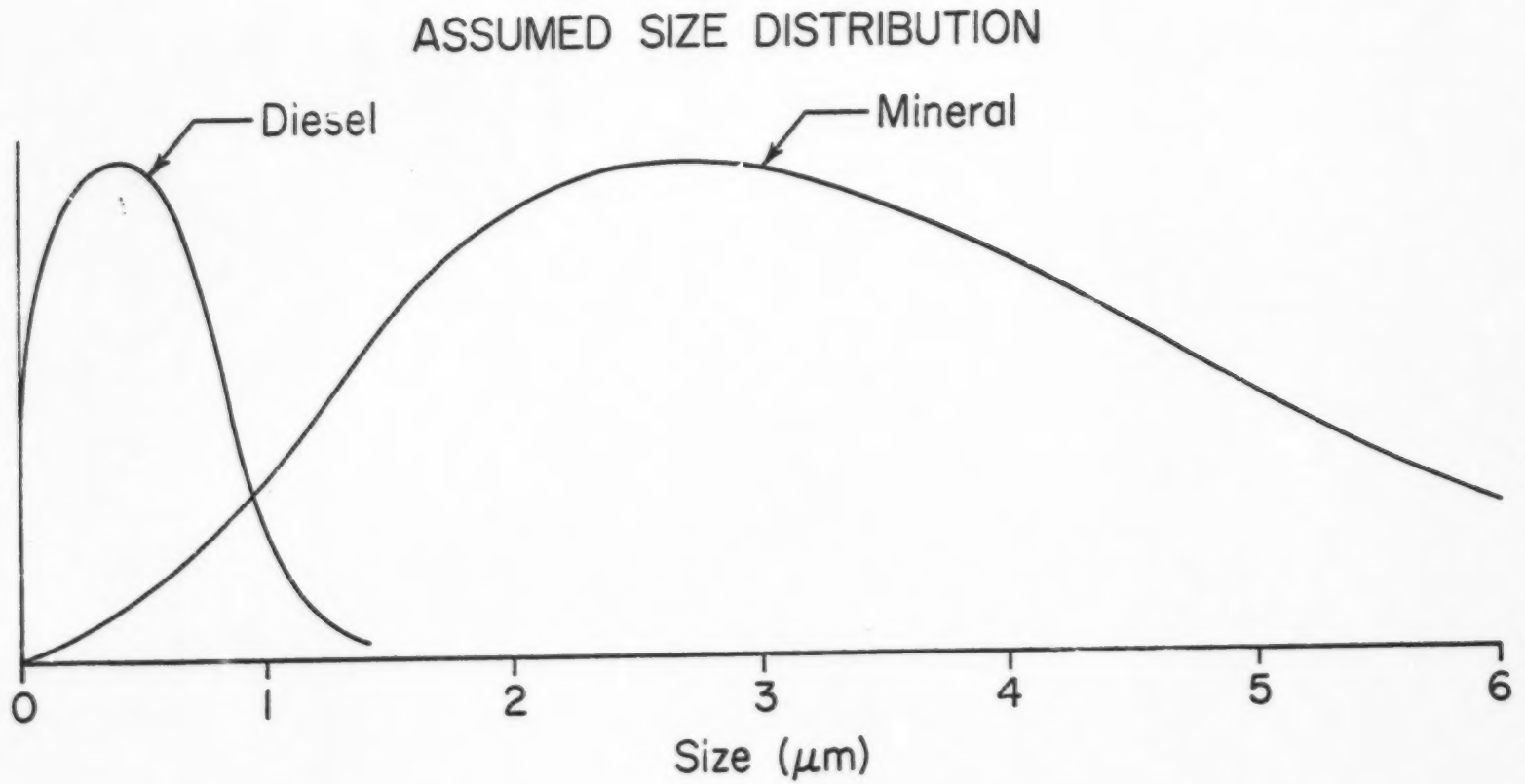

Fig. 6 - Ideal bimodal distribution of diesel and mineral particulates.

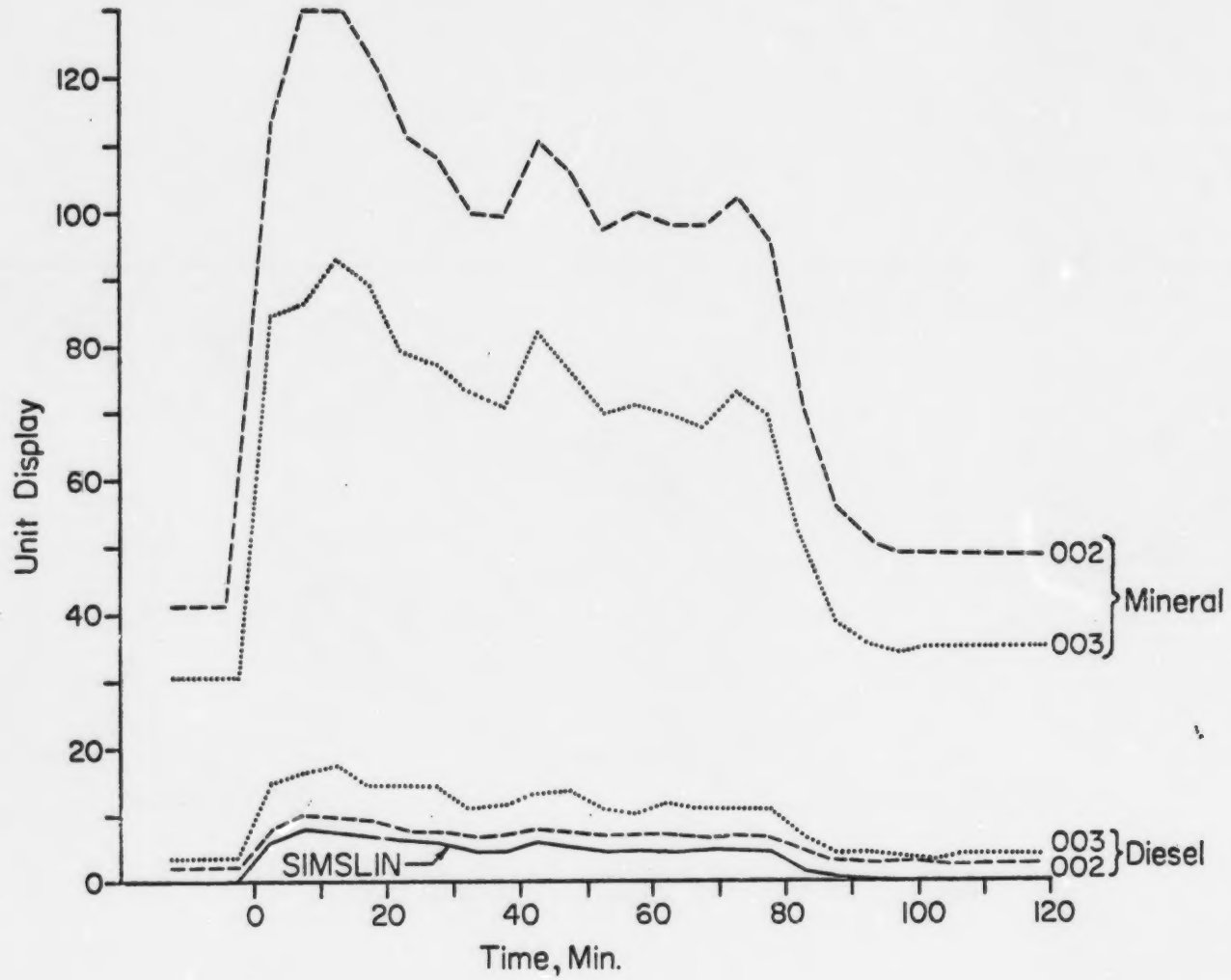

Fig. 7 - Unprocessed data of Simslin II and Metrex monitors for Test I.

Table 1 - Initial and processed data of Simslin II/Metrex sensor comparison for Test I.

Simslin Reading (mg/m^3)	Mineral/Diesel Unit No. 002									Mineral/Diesel Unit No. 003								
	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m^3)	Metrex Mass Conc. (mg/m^3)	Simslin Metrex Dev. (mg/m^3)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m^3)	Metrex Mass Conc. (mg/m^3)	Simslin Metrex Dev. (mg/m^3)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)
0	41.50					2.32				30.60					3.50			
6.30	113.20	71.34	11.32	5.75	0.55	8.00	5.66	12.60	0.00	84.32	53.50	8.49	6.42	-0.12	14.56	11.05	4.84	0.76
7.75	130.36	88.14	11.37	7.10	0.65	9.72	7.37	11.96	0.38	86.50	55.46	7.16	6.65	1.10	16.64	13.12	4.23	2.46
7.52	129.30	86.71	11.54	6.99	0.53	9.60	7.23	11.99	0.35	93.30	62.04	8.26	7.74	0.08	17.40	13.87	4.47	1.94
6.86	123.48	80.53	11.74	6.49	0.37	9.00	6.62	12.16	0.23	89.32	57.84	8.43	6.94	-0.08	14.30	10.76	5.37	-0.36
5.97	111.82	68.51	11.48	5.52	0.45	7.94	5.54	12.37	0.11	79.02	47.33	7.93	5.68	0.29	14.36	10.81	4.38	1.71
5.49	107.78	64.11	11.73	5.17	0.32	7.46	5.05	12.69	0.09	77.16	45.25	8.28	5.43	0.06	12.90	9.34	4.84	0.64
4.64	99.80	55.77	12.02	4.49	0.15	6.76	4.33	12.88	-0.09	73.06	40.93	8.82	4.91	-0.27	10.72	7.15	5.72	-0.72
4.74	99.68	55.29	11.66	4.46	0.26	6.94	4.49	12.31	0.11	71.02	38.67	8.16	4.64	0.10	11.60	8.02	4.82	0.68
5.94	110.28	65.52	11.03	5.28	0.66	7.80	5.34	12.27	0.15	82.20	49.63	8.35	5.95	-0.01	13.26	9.66	5.14	0.12
5.10	106.24	61.12	11.99	4.93	0.17	7.32	4.84	12.63	-0.01	76.10	43.31	8.50	5.20	-0.10	13.44	9.83	4.41	1.50
4.44	97.28	51.80	11.66	4.17	0.27	6.72	4.23	12.25	0.12	70.26	37.25	8.38	4.47	-0.03	10.96	7.34	5.07	0.18
4.58	100.16	54.32	11.85	4.38	0.20	6.80	4.29	12.66	-0.01	71.34	38.11	8.31	4.57	0.01	10.24	6.61	5.76	-0.72
4.27	98.36	52.16	12.22	4.20	0.07	6.76	4.24	12.30	0.11	69.86	36.41	8.53	4.37	-0.10	11.70	8.06	4.52	1.06
4.43	98.16	51.59	11.66	4.15	0.36	6.64	4.10	12.58	0.01	67.72	34.05	7.69	4.09	0.34	10.88	7.23	4.71	0.68
4.58	102.84	55.91	12.21	4.51	0.07	6.76	4.20	13.31	-0.23	73.26	39.37	8.60	4.72	-0.14	10.72	7.06	5.58	-0.51
4.16	96.30	49.01	11.78	3.95	0.21	6.58	4.01	12.22	0.12	69.70	35.60	8.56	4.27	-0.11	10.54	6.87	5.18	0.03
1.72	71.30	23.65	13.75	1.91	-0.19	4.52	1.93	12.23	0.06	51.54	17.24	10.02	2.07	-0.35	6.98	3.30	5.22	-0.01
0.40	56.08	8.07	13.49	0.65	-0.05	3.12	0.52	*15.53*	-0.12	38.94	4.40	7.36	0.53	0.07	4.60	0.91	4.83	0.06
0.15	50.90	2.52	*16.68*	0.20	-0.05	2.60	0.02	*126.00*	-0.18	35.68	0.92	*6.05*	0.11	0.04	4.26	0.56	*1.64*	0.38
0.02	49.30	0.56	*23.33*	0.04	-0.02	2.80	0.17	*3.29*	0.13	34.24	-0.74	-	-0.09	0.11	3.56	-0.45	-	-0.31
0.02	49.14	0.04	*2.50*	0.00	0.02	2.56	-0.09	-	-0.09	35.16	-0.04	-	0.00	0.02	3.00	-0.72	-	-0.71
0	49.10					2.65				35.20					3.72			
a	b	c	d	e	f	g	h	j	k	l	m	n	p	q	r	s	t	u

Italic values omitted from mineral sensitivity and mineral:diesel response ratio.

a) Calculate the average initial zeros per channel for each sensor (initial values of columns a,b,g,l and r).

b) Convert all sensor and Simslin data to five minute averages (columns a,b,g,l and r).

c) Calculate the average final zero per channel for each sensor (final values of columns a,b,g,l and r).

d) Correct the sensor 5 min averages for zero drift, (a linear correction has been applied), (columns c,h,m and s).

e) Calculate the sensitivity of the mineral channels for the sensors using 'corrected mineral/Simslin', e.g., c/a, (columns d and n).

f) Calculate the ratio of the mineral/diesel response per unit using 'corrected mineral/corrected diesel', e.g., c/h, (columns j and t).

g) Calculate the average mineral sensitivity and the mineral/diesel response ratios (columns d,j,n and t) for all five tests.

h) Apply the average mineral sensitivity to 'corrected mineral' to obtain the quantitative dust concentration (columns e and p).

i) Calculate the deviation of mineral concentrations from those given by the Simslin, e.g., a-e, (columns f and q).

j) Apply the average mineral/diesel response ratio to 'corrected mineral' to obtain the mineral contribution and subtract it from the 'corrected diesel', (columns k and u). This effectively gives the zero fluctuation of the diesel response after the mineral correction.

k) Calculate the average mineral deviation, the diesel fluctuation for each sensor, and the Simslin dust concentration for all five tests.

SENSOR MINERAL SENSITIVITIES AND MINERAL/DIESEL RESPONSE RATIOS

From the five tests the following constants were obtained, (unit 002 was not operational in Test V).

1) Diesel/mineral unit 002; using the Simslin II as a Standard for mineral:

   Average mineral sensitivity: 12.42 ± 0.73 (6%) units/mg/m^3.

   Inverse mineral sensitivity conversion applied = 0.0805 mg/m^3/unit.

   Average mineral/diesel response: 12.61 ± 0.54 (4%) units/units

   Inverse ratio response applied to 'zero' diesel = 0.0793.

2) Diesel/mineral unit 003; using the Simslin II as a standard for mineral:

   Average mineral sensitivity: 8.35 ± 0.77 (9%) units/mg/m^3.

   Inverse mineral sensitivity conversion applied = 0.120 mg/m^3/unit.

   Average mineral/diesel response: 5.20 ± 0.61 (12%) units/units.

   Inverse ratio response applied to 'zero' diesel = 0.1923.

CORRELATION OF MINERAL RESPONSES WITH THE SIMSLIN AND DIESEL ZERO FLUCTUATION

The final processed versions of the test results are plotted in Fig. 8 to 12. Mineral responses plotted are the Simslin, and the two responses converted to mg/m^3. Diesel responses plotted are the diesel 'zeros' after being corrected for mineral contribution.

Throughout the tests very good mineral agreement with the Simslin is apparent, especially in Test IV, Fig. 11. Deviation analyses gave:

Unit 002; mineral deviation 0.05 ± 0.43 mg/m^3.

Unit 003; mineral deviation 0.02 ± 0.59 mg/m^3.

In terms of the average and peak mineral concentrations throughout the tests, (5.30 mg/m^3 and 15.11 mg/m^3) these deviations represent:

Unit 002: 0.9 ± 8.1% to the mean ; 0.3 ± 2.8% to the peak

Unit 003: 0.4 ± 11.2% to the mean ; 0.1 ± 3.9% to the peak.

For the preceding data treatment, the above analyses show an excellent correlation between the sensors and Simslin II unit.

In Fig. 8 to 12, it is obvious that the diesel 'zero' still fluctuates. This appears excessive, but it has not been scaled as with mineral response.

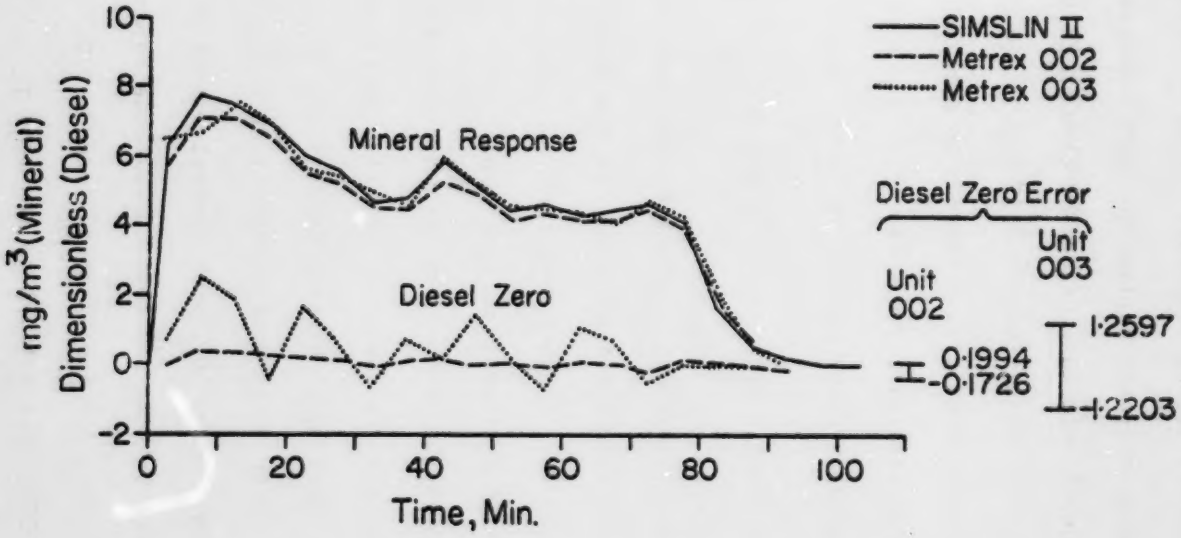

Fig. 8 - Processed Metrex mineral responses as calibrated against Simslin II response, and diesel zero fluctuation for Test I.

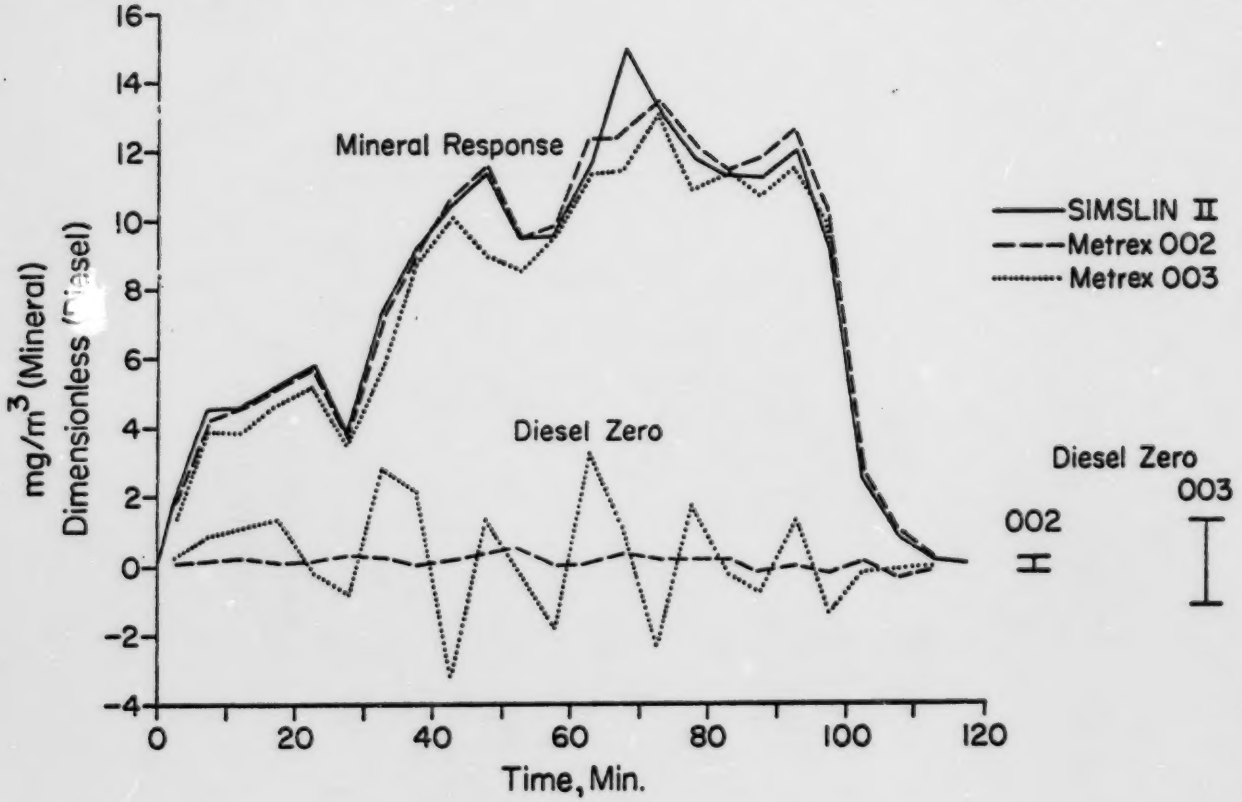

Fig. 9 - Processed Metrex mineral responses as calibrated against Simslin II response, and diesel zero fluctuation for Test II.

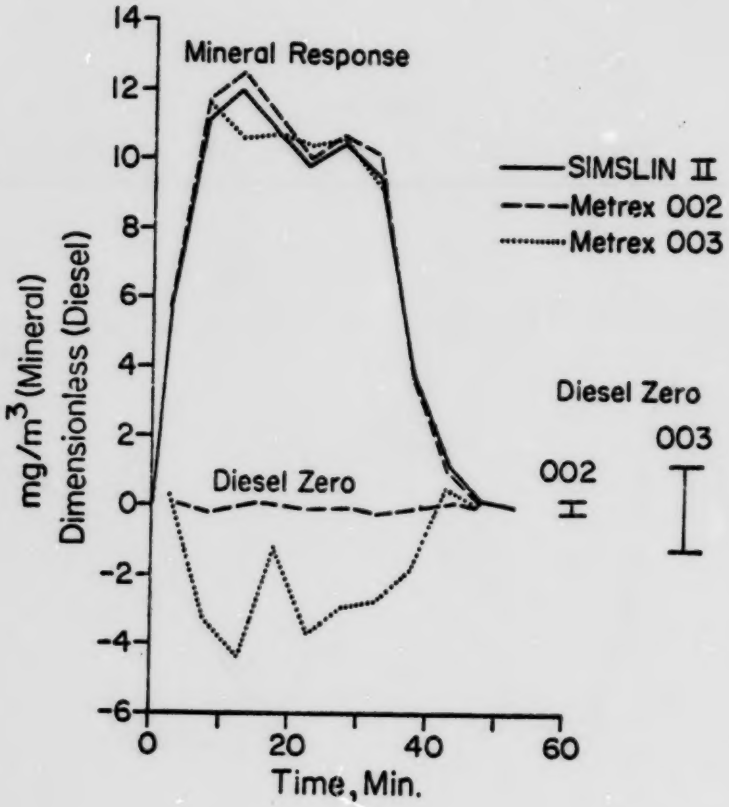

Fig. 10 - Processed Metrex mineral responses as calibrated against Simslin II response, and diesel zero fluctuation for Test III.

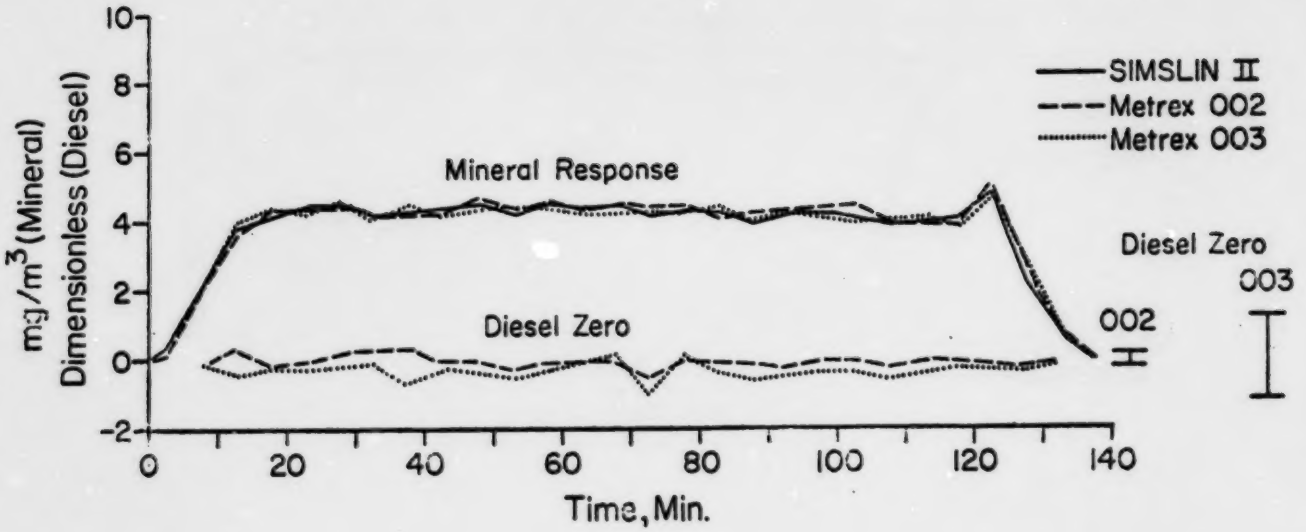

Fig. 11 - Processed Metrex mineral responses as calibrated against Simslin II response, and diesel zero fluctuation for Test IV.

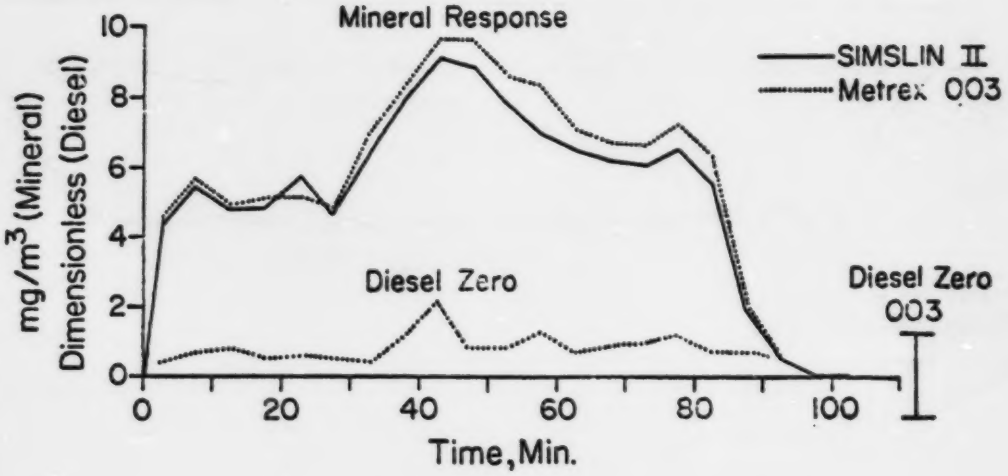

Fig. 12 - Processed Metrex mineral responses as calibrated against Simslin II response, and diesel zero fluctuation for Test V.

Whether this variation is significant can only be determined through pure diesel sensitivity testing. Deviation analyses gave:

Unit 002: diesel 'zero' deviation 0.01 $\pm$ 0.19 units

Unit 003: diesel 'zero' deviation 0.02 $\pm$ 1.24 units.

If the diesel sensitivity of these two units are similar, it would appear that unit 003 is more susceptible to mineral interaction.

ZERO DRIFT

Generally, the Metrex sensors compare very favourably with the Simslin II as dust monitors. However, a major technical problem that needs solving or accounting for is zero drift and dust deposition in the sensing volume. Mineral drift was:

1. Unit 002 drifted fairly consistently at 0.017, 0.02, 0.02, 0.02 units/average (mg/m^3)/min of dust exposure in the respective tests.
2. Unit 003 was less consistent at 0.01, 0.006, 0.009, 0.005, 0.008 units/mg/m^3/min.

Associated diesel drift was:

a) Unit 002; 0.0007m 0.0008, 0.0007, 0.0005 units/mg/m^3/min.

b) Unit 003; 0.0005, 0.0009, 0.0006, 0.0004, 0.0013 units/mg/m^3/min.

For each unit and channel the drift has the same order of magnitude. It may be feasible to include a zero drift correction in the signal processing if it can be shown to be a pure function of dust concentration and time. However, special consideration will have to be given to clouds of greater than respirable size dust which the monitor ignores, but which can readily form a sediment.

A zero drift correction should be explored in further calibration tests.

If the drift cannot be internally compensated for, another method of

zero drift correction is needed. This may necessitate special provision to keep the optics and background surfaces clean.

CONCLUSIONS

As mineral sensors, the Metrex diesel/mineral monitors appear excellent. In this initial trial, a comparison with a Simslin II unit, the average agreements of both sensors was within 10% at 5 mg/m^3 dust concentrations.

This agreement was reached after corrections for mineral sensitivity of the sensors, on average 10 units/mg/m^3, and zero drift. In pure respirable particulate clouds a concentration/time drift compensation may be sufficient. This could be 0.01 to 0.02 units/(mg/m^3)/min at the above sensitivity.

The interaction of mineral appearing as diesel was less clear as the relative sensitivity of the two sensors to diesel was unknown. However, it was found that 10 and 20% of mineral responses appear as diesel on the individual diesel displays and the zero drift was of the order of 0.0007 units/(mg/m^3)/min.

These units should prove to be relatively inexpensive sensors for rapid data acquisition of respirable dust and possibly diesel.

REFERENCES

1. Hardcastle, S.G., "Dust concentrations as a function of air velocity in mines"; Division Report 84-72(TR); CANMET, Energy, Mines and Resources Canada; May 1984.

2. Metrex Instruments Ltd., "Development of sensors for separate assessments of diesel exhaust particulates and respirable mineral dust in mine atmosphere"; Final Report for Contract 26SQ. 23440-3-9091.

APPENDIX

Table A-1 - Initial and processed data of Simslin II/Metrex sensor comparison for Test II.

	Mineral/Diesel Unit No. 002									Mineral/Diesel Unit No. 003								
Simslin Reading (mg/m^3)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/ mg/m^3)	Metrex Mass Conc. (mg/m^3)	Simslin Metrex Dev. (mg/m^3)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/ units)	Diesel 'Zero' (units)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/ mg/m^3)	Metrex Mass Conc. (mg/m^3)	Simslin Metrex Dev. (mg/m^3)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/ units)	Diesel 'Zero' (units)
0	49.10					2.54				35.50					3.58			
1.81	72.82	22.98	12.70	1.85	-0.04	4.52	1.95	11.78	0.13	47.30	11.57	6.39	1.39	0.42	6.12	2.51	4.61	0.29
4.53	103.16	52.57	11.60	4.24	0.29	6.92	4.32	12.17	0.15	68.72	32.76	7.23	3.93	0.60	10.88	7.24	4.52	0.94
4.58	108.96	57.63	12.58	4.64	0.06	7.40	4.77	12.08	0.20	68.48	32.30	7.05	3.88	0.70	11.08	7.40	4.36	1.19
5.21	115.88	63.80	12.24	5.14	0.07	7.80	5.14	12.41	0.08	75.68	39.27	7.53	4.71	0.50	12.60	8.89	4.42	1.34
5.78	124.22	71.40	12.36	5.75	0.03	8.48	5.79	12.33	0.13	79.62	42.98	7.44	5.16	0.62	11.78	8.04	5.34	-0.22
4.88	112.48	58.92	12.08	4.75	0.13	7.66	4.94	11.93	0.27	74.28	37.41	7.67	4.49	0.39	10.16	6.38	5.86	-0.81
7.42	144.58	90.27	12.17	7.28	0.14	10.08	7.33	12.31	0.17	84.38	47.28	6.37	5.74	1.68	15.62	11.81	4.00	2.72
9.22	168.50	113.45	12.30	9.14	0.08	11.80	9.02	12.58	0.02	110.60	73.00	7.92	8.76	0.46	20.00	16.16	4.52	2.12
10.44	187.53	131.73	12.61	10.62	-0.18	13.38	10.57	12.46	0.12	121.51	83.96	8.04	10.07	0.37	16.83	12.96	6.48	-3.18
11.37	198.74	142.20	12.51	11.46	-0.13	14.44	11.60	12.26	0.32	113.16	75.38	6.63	9.05	2.32	19.72	15.81	4.77	1.32
9.54	175.08	117.80	12.35	9.49	0.05	12.70	9.83	11.98	0.49	109.26	71.25	7.47	8.55	0.99	17.58	13.64	5.22	-0.06
9.59	179.64	121.61	12.69	9.80	-0.21	12.58	9.68	12.56	0.04	118.38	80.14	8.36	9.62	-0.03	17.60	13.63	5.88	-1.78
11.61	212.74	153.97	13.26	12.41	-0.80	15.22	12.29	12.53	0.08	132.92	94.46	8.14	11.33	0.28	25.42	21.41	4.41	3.25
15.11	213.34	153.82	10.18	12.40	2.71	15.52	12.56	12.25	0.36	134.08	95.39	6.31	11.45	3.66	23.48	19.44	4.91	1.10
13.18	227.20	166.94	12.67	13.45	-0.27	16.40	13.41	12.45	0.17	147.72	108.80	8.25	13.06	0.12	22.92	18.85	5.77	-2.37
11.88	212.76	151.76	12.77	12.23	-0.35	15.24	12.21	12.43	0.18	130.42	91.27	7.68	10.95	0.93	23.46	19.36	4.71	1.81
11.28	203.82	142.07	12.59	11.45	-0.17	14.52	11.46	12.40	0.19	135.26	95.88	8.50	11.51	-0.23	22.48	18.34	5.23	-0.10
11.23	209.76	147.27	13.11	11.86	-0.63	14.54	11.45	12.86	-0.23	128.26	88.66	7.89	10.64	0.59	20.46	16.29	5.44	-0.76
12.01	219.76	156.52	13.03	12.61	-0.60	15.50	12.38	12.64	-0.03	135.92	96.09	8.00	11.53	0.48	24.08	19.88	4.83	1.40
9.36	189.60	125.62	13.42	10.12	-0.76	12.88	9.73	12.91	-0.23	122.98	82.92	8.86	9.95	-0.59	18.82	14.58	5.69	-1.36
2.46	97.92	33.20	13.49	2.67	-0.21	5.92	2.74	12.12	0.11	61.80	21.51	8.74	2.58	-0.14	8.22	3.95	5.44	-0.19
0.87	78.30	12.83	14.78	1.03	-0.16	3.94	0.73	*17.57*	-0.29	49.54	9.03	10.40	1.08	-0.21	5.98	1.68	5.37	-0.06
0.20	69.84	3.63	*18.52*	0.29	-0.09	3.36	0.12	*30.25*	-0.17	43.46	2.72	*13.88*	0.33	-0.13	4.84	0.51	5.33	-0.01
0.07	67.40	0.44	*6.11*	0.03	0.04	3.36	0.09	*4.89*	0.06	42.36	1.39	*19.30*	0.17	-0.10	4.44	0.07	*19.86*	-0.14
0.04	67.38	-0.32	-	-0.03	0.07	3.30	0.00	-	0.02	41.98	0.78	*19.50*	0.09	-0.05	4.52	0.12	*6.50*	-0.03
0	67.70					3.30				41.20					4.40			

Table A-2 - Initial and processed data of Simslin II/Metrex sensor comparison for Test III.

Simslin Reading (mg/m³)	Mineral/Diesel Unit No. 002									Mineral/Diesel Unit No. 003								
	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m³)	Metrex Mass Conc. (mg/m³)	Simslin Metrex Dev. (mg/m³)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m³)	Metrex Mass Conc. (mg/m³)	Simslin Metrex Dev. (mg/m³)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)
0	67.14					3.30				42.10					4.30			
5.45	136.42	68.65	12.60	5.65	-0.20	8.72	5.40	12.71	0.09	89.44	47.07	8.64	5.53	-0.08	13.62	9.30	5.06	0.25
11.09	213.60	145.20	13.09	11.61	-0.52	14.66	11.31	12.84	-0.20	139.44	96.79	8.73	11.70	-0.61	19.64	15.30	6.33	-3.31
11.95	222.98	153.95	12.88	10.58	1.37	15.54	12.17	12.65	-0.04	131.06	88.14	7.38	12.41	-0.46	25.70	21.34	4.13	-4.39
10.86	209.12	139.46	12.86	10.70	0.14	14.56	11.17	12.48	0.11	132.38	89.18	8.23	11.24	-0.40	20.24	15.85	5.63	-1.30
9.79	194.82	124.53	12.72	10.35	-0.56	13.22	9.80	12.70	-0.07	129.74	86.27	8.81	10.02	-0.23	17.32	12.91	5.68	-3.68
10.44	203.76	132.84	12.72	10.63	-0.19	13.98	10.54	12.60	-0.01	132.36	88.61	8.49	10.71	-0.27	18.58	14.15	6.26	-2.69
9.55	196.98	125.43	13.13	8.99	0.56	13.16	9.70	12.93	-0.25	118.94	74.92	7.84	10.11	-0.56	16.10	11.65	6.43	-2.76
4.12	123.68	51.50	12.50	3.88	0.24	7.46	3.97	12.97	-0.11	76.62	32.32	7.84	4.15	-0.03	8.78	4.31	7.50	-1.90
1.27	87.56	14.75	11.61	1.29	-0.02	4.80	1.29	11.43	0.12	56.30	10.73	8.45	1.19	0.08	7.06	2.56	4.19	0.50
0.16	75.18	1.74	11.01	0.20	-0.04	3.68	0.14	12.43	0.00	46.54	1.69	10.70	0.14	0.02	4.94	0.42	4.02	0.10
0.06	75.12	1.05	*10.41*	0.01	0.05	3.50	-0.06	-	-0.14	45.24	0.12	*1.87*	0.08	-0.02	4.70	0.16	*0.75*	0.14
0	74.70					3.56				45.40					4.54			

Table A-3 - Initial and processed data of Simslin II/Metrex sensor comparison for Test IV.

Simslin Reading (mg/m³)	Mineral/Diesel Unit No. 002									Mineral/Diesel Unit No. 003								
	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m³)	Metrex Mass Conc. (mg/m³)	Simslin Metrex Dev. (mg/m³)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/mg/m³)	Metrex Mass Conc. (mg/m³)	Simslin Metrex Dev. (mg/m³)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/units)	Diesel 'Zero' (units)
0	73.34					3.76				43.80					4.50			
0.31	74.98	1.28	4.13	0.10	0.21	4.00	0.23	5.65	0.21	46.38	2.49	8.03	0.30	0.01	5.02	0.51	4.88	0.03
2.15	100.20	26.14	12.16	2.11	0.04	5.64	1.86	14.05	-0.21	59.80	15.83	7.36	1.90	0.25	7.22	2.71	5.84	-0.15
3.80	117.58	43.16	11.37	3.48	0.32	7.52	3.73	11.57	0.29	76.84	32.78	8.63	3.91	-0.13	10.36	5.84	5.61	-0.46
4.23	128.10	53.32	12.60	4.30	-0.07	7.88	4.08	13.07	-0.15	79.78	35.64	8.42	4.28	-0.05	11.10	6.57	5.42	-0.28
4.40	129.04	53.90	12.25	4.34	0.06	7.96	4.15	12.99	-0.12	79.48	35.25	8.01	4.23	0.17	11.02	6.48	5.44	-0.30
4.45	129.78	54.28	12.20	4.37	0.08	8.32	4.50	12.06	0.23	81.58	37.26	8.37	4.47	-0.02	11.50	6.96	5.35	-0.20
4.22	127.88	52.02	12.33	4.19	0.03	8.27	4.40	11.82	0.28	78.58	34.18	8.10	4.10	0.12	11.02	6.47	5.28	-0.10
4.28	128.12	51.90	12.11	4.18	0.10	8.22	4.39	11.82	0.28	82.00	37.51	8.76	4.50	-0.22	11.04	6.48	5.78	-0.73
4.29	129.28	52.69	12.28	4.25	0.04	7.92	4.08	12.91	-0.10	79.94	35.37	8.24	4.24	0.05	11.06	6.50	5.44	-0.30
4.46	134.80	57.85	12.97	4.66	-0.20	8.42	4.57	12.66	-0.02	81.42	36.76	8.24	4.41	0.05	11.24	6.69	5.49	-0.38
4.22	130.36	53.05	12.57	4.27	-0.05	7.78	3.92	13.53	-0.29	80.68	35.93	8.51	4.31	-0.09	10.92	6.34	5.67	-0.57
4.48	134.26	56.57	12.63	4.56	-0.08	8.26	4.39	12.89	-0.10	82.28	37.75	8.43	4.53	-0.05	11.40	6.81	5.54	-0.45
4.35	131.46	53.43	12.28	4.31	0.04	8.08	4.20	12.72	-0.04	80.32	35.40	8.14	4.25	0.10	11.28	6.69	5.29	-0.12
4.47	133.74	55.35	12.38	4.46	0.01	8.28	4.39	12.61	0.0	80.08	35.07	7.85	4.21	0.26	11.42	6.82	5.14	0.08
4.20	132.78	54.03	12.86	4.35	-0.15	7.60	3.70	14.60	-0.58	80.60	35.55	8.46	4.27	-0.07	10.44	5.83	6.10	-1.01
4.34	134.20	55.09	12.69	4.44	-0.10	8.24	4.33	12.72	-0.04	80.32	35.15	8.10	4.22	0.12	11.40	6.79	5.18	0.03
4.24	130.50	51.03	12.03	4.11	0.13	7.84	3.92	13.02	-0.13	81.98	36.72	8.66	4.41	-0.17	11.28	6.66	5.51	-0.40
3.94	131.84	52.01	13.20	4.19	-0.25	7.92	3.99	13.03	-0.13	78.44	33.09	8.40	3.97	-0.03	10.40	5.77	5.73	-0.59
4.20	133.32	53.13	12.65	4.28	-0.08	7.88	3.94	13.48	-0.27	80.64	35.21	8.38	4.22	-0.02	10.84	6.20	5.68	-0.55
4.25	134.94	54.39	12.80	4.38	-0.13	8.24	4.29	12.68	-0.02	80.30	34.78	8.18	4.17	0.08	10.86	6.22	5.59	-0.42
4.12	135.80	54.89	13.32	4.42	-0.30	8.24	4.29	12.79	-0.06	79.58	33.97	8.24	4.08	0.04	10.78	6.13	5.54	-0.40
3.91	130.66	49.39	12.63	3.98	-0.07	7.64	3.68	13.42	-0.24	79.52	33.83	8.65	4.06	-0.15	10.56	5.90	5.73	-0.60
3.98	129.56	47.93	12.04	3.86	0.12	7.66	3.69	12.99	-0.11	79.52	33.74	8.48	4.05	-0.07	10.72	6.06	5.57	-0.43
4.07	131.14	49.14	12.07	3.96	0.11	7.74	3.76	13.07	-0.14	79.10	33.23	8.16	3.99	0.08	10.82	6.15	5.41	-0.24
4.93	145.02	62.67	12.71	5.05	-0.12	8.72	4.73	13.25	-0.24	85.50	39.55	8.02	4.75	0.18	12.02	7.34	5.39	-0.26
2.30	114.90	32.19	13.99	2.59	-0.29	6.30	2.30	14.00	-0.25	68.72	22.68	9.86	2.72	-0.42	8.70	4.01	5.66	-0.35
0.72	92.80	9.73	13.59	0.78	-0.06	4.76	0.75	12.97	-0.02	52.84	6.71	9.37	0.80	-0.08	5.86	1.17	5.73	-0.12
0.04	84.20	0.77	20.26	0.06	-0.02	3.90	-0.12	-	0.06	47.12	0.71	23.95	0.11	-0.07	4.86	0.16	5.69	-0.01
0	83.80					4.02				46.30					4.70			

Table A-4 - Initial and processed data of Simslin II/Metrex sensor comparison for Test V.

	Mineral/Diesel Unit No. 003								
Simslin Reading (mg/m^3)	Mineral Reading (units)	Drift Corrected Mineral (units)	Metrex Simslin Ratio (units/ mg/m^3)	Metrex Mass Conc. (mg/m^3)	Simslin Metrex Dev. (mg/m^3)	Diesel Reading (units)	Drift Correct Diesel (units)	Mineral Diesel Ratio (units/ units)	Diesel 'Zero' (units)
0	8.50					2.90			
4.28	45.78	37.08	8.67	4.54	-0.26	10.46	7.53	4.92	0.40
5.39	56.92	48.02	8.92	5.76	-0.37	12.86	9.89	4.85	0.66
4.80	49.98	40.88	8.52	4.91	-0.11	11.64	8.64	4.73	0.78
4.81	52.22	42.92	8.92	5.15	-0.36	11.76	8.73	4.92	0.48
5.67	52.24	42.74	7.54	5.13	-0.54	11.88	8.81	4.85	0.59
4.65	49.34	39.64	8.52	4.76	-0.09	11.20	8.10	4.89	0.48
6.30	66.66	56.76	9.01	6.81	-0.51	14.44	11.31	5.28	0.40
7.91	79.78	69.68	8.81	8.36	-0.45	17.68	14.51	4.80	1.11
9.04	91.58	81.28	8.99	9.75	-0.71	20.92	17.72	4.59	2.09
8.84	92.02	81.52	9.23	9.78	-0.94	19.74	16.51	4.94	0.83
7.85	82.92	72.22	9.20	8.66	-0.81	17.94	14.67	4.92	0.78
7.51	80.56	69.66	9.27	8.36	-0.85	17.94	14.64	4.76	1.25
6.44	71.06	59.96	9.31	7.19	-0.75	15.56	12.23	4.90	0.70
6.25	67.84	56.54	9.05	6.76	-0.51	15.04	11.67	4.84	0.84
6.11	67.62	56.12	9.18	6.73	-0.62	15.10	11.70	4.80	0.91
6.52	72.78	61.08	9.37	7.33	-0.81	16.26	12.83	4.76	1.08
5.50	64.52	52.62	9.57	6.31	-0.81	14.28	10.81	4.87	0.69
2.01	31.46	19.36	9.64	2.32	-0.31	7.58	4.08	4.74	0.36
0.60	17.38	5.08	8.44	0.61	-0.01	4.98	1.45	*3.50*	0.47
0.04	12.54	0.04	*0.91*	0.00	0.04	4.02	0.45	*0.09*	0.44
0.01	13.20	0.50	*50.00*	0.60	-0.05	3.70	0.10	*5.00*	0.00
0	12.70					3.60			